Attorney Docket No. 80095

INSTRUMENTED FIBER OPTIC TOW CABLE

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT (1) ANTHONY A. RUFFA, (2) THOMAS R. STOTTLEMYER and (3) PETER E. SEAMAN, citizens of the United States of America, employees of the United States Government and residents of (1) Hope Valley, County of Washington, State of Rhode Island, (2) Mystic, County of New London, State of Connecticut and (3) Niantic, County of New London, State of Connecticut have invented certain new and useful improvements entitles as set forth above of which the following is a specification:

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DATE OF SIGNATURE

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STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The instant invention relates to an instrumented cable using optical fiber for many types of measurements, and more particularly to measure the temperature profile of a body of water as a function of depth using an instrumented fiber optic tow cable and to measure a temperature profile for oil wells.

(2) Description of the Prior Art

There are several approaches for measuring temperature with fiber-optic-based sensors that are already available in the prior art. However, one of the main obstacles of using this technique is to design a system that is sufficiently rugged to survive deployment and retrieval through handling systems at high tensions over a limited diameter sheave or a winch. Nonetheless, the use of optical fibers to measure various physical parameters such as light transmission in different media is on the increase due to the compact size and the ease of operation of optical

fiber detectors in various environments. As an example, use of optical fibers to measure the temperature profile of a body of water as a function of depth is quite important as the water temperature affects the propagation of acoustic waves in the body of water and thus affects sonar performance. The temperature of the water is also important to the fishing industry, because some species of fish stay within water having very precise temperature bounds. Still another area of interest is to measure temperature profile in an oil well. It is thus desirable to integrate an optical fiber tow cable as a detector for making measurements of various parameters including temperature profile of a body of water and/or and oil well using a state-of-the art tow cable with optical fibers.

SUMMARY OF THE INVENTION

In accordance with the principal object of the present invention, an armored fiber optic cable is integrated with the means for measuring temperature of a body of water and/or obtaining temperature profile in an oil well. In the fiber optic tow cable, a plurality of optical fibers enclosed in tubes are interspersed among the armor wires comprising either a typical double-plow steel wire or KEVLAR™ fiber tow cable as taught by Holmberg in U.S. Patent No. 5,212,755; dated 18 May 1993, assigned to the United States of America as represented by the Secretary of the Navy. A series of temperatures sensors are incorporated into the optical fibers integrated in the tow cable. This patent is incorporated by reference in subject patent

application. Subject invention further teaches the use of a light source which illuminates on the optical fibers used and the scattered light is received by a receiver which sends the signals for processing in a processor to obtain temperature profile of the body of water or that of an oil well as a function of depth.

It is an object of subject invention to integrate fiber optic sensors into a state-of-the-art tow cable.

Still another object of subject invention is to use temperature sensors in conjunction with the optical fibers to measure a temperature profile of a body of water.

Still another object of subject invention is to use an instrumented tow cable to measure a temperature profile of an oil well.

Another object of subject invention is to use steel armor wires to protect the optical fibers used in the system.

Another object of subject invention is to use KEVLAR™ fibers or wires to protect the optical fibers used in the system for measuring temperature profile.

Still another object of subject invention is to use the optical fibers fitted with temperature sensors in the outer most layer wherin either armor steel wires or armor KEVLAR™ fibers are used as armor wires.

Other objects features and advantages of the invention shall become apparent as the description thereof proceeds when considered in connection with accompanying illustrative drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same become better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a diagrammatic representation of an integrated tow cable which uses armor steel wires; and

FIG. 2 is another diagrammatic representation of an integrated tow cable which uses armor KEVLAR™ fibers.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, a first embodiment of an instrumented fiber optic tow cable system 10 according to the teachings of subject invention is diagrammatically shown which includes a steel armored, low strain fiber optic cable 12. Here, low strain is defined as an amount of strain that is sufficiently small so that the optical fibers are not strained to the point of damage. Cable 12 is made of a cable core 14 which may also contain electrical conductors (not shown) to carry electric power and signals, a core jacket 16 to prevent water intrusion into the cable core 14, armor wires 18, arranged in one or more layers, and optical fibers 20 interspersed in the outermost layer to expose the optical fibers 20 to the temperature of the fluid under investigation. It should be noted that the temperature sensors (not shown) are attached integrally to optical fibers 20.

It should also be noted that in embodiment 1 as shown in FIG. 1, optical fibers 20 are enclosed in preferrably steel tubes 22. The method of enclosing optical fibers in stainless steel tubes is standard in the telecommunications industry. The stainless steel tube replaces one armor wire, and thus has a diameter equal to or less than that of the replaced armor wire. Alternatively, as shown in FIG. 1, in order to preserve their integrity, the optical fibers 20 are surrounded by preferrably steel armor wires 23 of smaller diameter than that armor wires 18. The bundle of armor wires 23 replaces an armor wire 18 and has a diameter equal to or less than the replaced armor wire 18. A KEVLAR™ braided fiber-based sleeve (not shown) maybe placed around the outer layer of armor steel wires to keep them together as one unit. The method disclosed here is distinguished from the Holmberg patent in that the steel tube (or steel armor wire bundle) containing the optical fiber is located in the *outer* armor wire layer. As mentioned before, one of the main obstacles of using this technique is to design a system that is sufficiently rugged to survive deployment and retrieval through handling systems at high tensions over a limited diameter sheave or a winch. This was sufficiently proven in tests with a 1.6″ diameter steel cable that was tested under realistic simulated handling conditions. Specifically, for the 1.6″ steel cable, repeated cyclic bend-over-sheave tests at tensions of up to 22,000 lb over a 46″ diameter sheave were conducted successfully. A light source 26 is used to show light to the optical fibers 20 which scatter the light to provide information about the temperature of the fluid.

The scattered light is received by receiver 28 and processed by processor 30 to obtain the information about the temperature of the fluid at a particular location. The preferred method is to make use of Raman scattering effects to infer the distributed temperature along the fiber. It is established in the prior art that such methods can provide a distributed measurement with ½ meter resolution along the fiber. In Instrumented Tow Cable tests, the measurements differed from XBT (Expendable Bathythermograph) measurements by $0.2C^{\circ}$ (standard deviation) or less. It should be noted that the KEVLAR™ braid allows the water or the fluid under investigation to impinge on the optical fibers and the temperature detectors to measure the true temperature at a particular location. It should also be noted that processor 30 used for this analysis is a PC (personal computer) based system and is commercially available and it may also include a display unit (not shown). The second embodiment of the integrated fiber optic tow cable system 40 is shown in FIG. 2 which uses tow cable 42 which has a plurality of armor KEVLAR™ fibers 44, having optical fibers 46. Surrounded by KEVLAR™ fibers 48 as shown. The processing is done by using a light source 26, a receiver 28 and a processor 30. It should be noted that the optical fibers can be enclosed in steel tubes to preserve their integrity instead of surrounding them by armor wires. Although only one optical fiber is needed for operation of the instrumented cable, in practice, more than one optical fiber (enclosed in a steel tube or in a bundle of smaller armor wires)

is incorporated into the outer layer of armor wires for redundancy.

It should be noted that the inventive concept of subject invention is the concept of integration of optical fibers with the system of measuring the temperatures at various depths of a fluid. The system of measuring the temperatures using a light source, a receiver and a processor can be varied without deviating from the teachings of subject invention.

Another preferred method for measuring temperature is via Raman scattering coupled with an adaptation of Optical Time Domain Reflectometry (OTDR). This provides a direct measurement of the temperature over cells determined by a type of time of arrival processing of the scattered energy.

While there is shown and described herein certain specific structure embodying the invention, it will be mainifested to those skilled in the art that various modifications and rearrangements of the parts may be made without departing from the spirit and scope of the underlying inventive concept. As an example, armor wires could be either steel wires or KEVLAR™ fibers. Furthermore, the system for measuring the temperature of the fluid as a function of depth of a fluid using a light source, a receiver and a processor can be varied without deviating from the teachings of subject invention except insofar are indicated by the scope of the appended claims.